The average reverberation intensity (ARI) of short pulse in shallow water is proportional to the pulse length. If the ARI of a long pulse signal can be treated as the superposition of that of several short pulse signals, then the average intensity and the duration of reverberation of the long pulse signal should increase linearly with the pulse length. So an experiment has been conducted to verify this assumption and theoretical analyses the effect of pulse length on low frequency ARI in shallow-water has also been made.

Fig.1 shows the geometry of the shallow water waveguide during the experiment. The salinity is 35‰ and the depth of water is about 87m. Both Continuous Wave (CW) and Linear Frequency Modulate (LFM) were transmitted by the shark’s-lip type transducer. The receive systems are two vertical linear arrays 1 kilometer and 10 kilometer away from the source. The depth of source is 15m.

Fig.2 The sound velocity profile

Fig.3 shows the comparison of the decaying rule of the ARI for different pulse lengths. It shows that the duration of the reverberation will last longer and the ARI will be stronger with the pulse length being longer. But Fig.4 shows the increasing rates with pulse length can reach to 0, i.e. the duration and intensity of reverberation will reach a constant if the pulse length is long enough. So the ARI in shallow water is a joint effect of range, pulse length and background ambient noise.

The weighting parameters of ARI determined by the two-way propagation loss will enhance with reverberation-ambient noise ratio being low.

**Theoretical Analysis:**

The ARIs of short pulse in shallow-water can be expressed as

$$I_r(t, \tau) = Kte^{-\beta t}t_m = Ar$$

A is dependent on T and $\beta$, K is a constant which is proportional to the source level and scattering coefficient. m is depending on the principle of reverberation, propagation condition and the directivity of the transmitting and receiving transducer. But the transmission loss, the scattering intensities of the long pulse for different ranges in the scatter area are different. This cannot be ignored. So the ARI of pulse length 1 can be expressed as

$$I_r(t, \tau) = \int_{t_1}^{t_2} Ke^{-\beta \xi} d\xi = K \int_{t_1}^{t_2} d\xi \sum_{k=1}^{\infty} (-\beta \xi)^k k!$$

$$= K \sum_{k=1}^{\infty} (-\beta)^k \frac{k!}{t^{k-1}} [(1 + \frac{\tau}{k}) - 1]$$

$$+ (-\beta)^{m-1} (\frac{1}{m-1})! [\ln(1 + \frac{\tau}{m})]$$

$$\tau / t < 1$$

$$I_r(t, \tau) = \frac{Kte^{-\beta t}}{t_m} - \frac{1}{2!} K\tau^2 e^{-\beta \tau} t_m + \frac{1}{3!} K\tau^3 e^{-\beta \tau} t_m + \cdots$$

The ARI in Pekeris waveguide can be written as

$$I_r(t, \tau) = \frac{Kte^{-\beta t}}{t} - \frac{1}{2!} K\tau^2 e^{-\beta \tau} (\frac{\beta}{t} + \frac{1}{t^2})$$

$$+ \frac{1}{3!} K\tau^3 e^{-\beta \tau} (\frac{\beta^2}{t^2} + \frac{2\beta}{t^3}) + \cdots$$

The first term of the ARI is similar to that of a short pulse, and the others are corrections because of the propagation loss.

**Discussion and Conclusions:**

1. The low frequency and long range ARI in shallow water increases with transmitted signal pulse length nonlinearly, which is the balancing effect of range, pulse width and background ambient noise. And the increasing rate of the ARI can reach to 0, which means the ARI will get a constant when the pulse length is long enough.
2. The difference between the horizontal ranges of different scatterers in the scattering area cannot be ignored. So the scattering strength at different range in the scattering area weighted by two-way propagation loss also causes the ARI increase with pulse length nonlinearly.
3. The weighting parameters caused by the two-way propagation loss will be changed when the ratio of reverberation intensity and ambient noise intensity is low.